BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: Status of Electromagnetic Interference Control in the Apollo Applications Program Case 620

DATE: September 5, 1968

FROM: A. G. Weygand

ABSTRACT

The current electromagnetic interference (EMI) control and electromagnetic compatibility (EMC) validation efforts of the NASA Centers and intercenter panels in the Apollo Applications Program (AAP) for missions AAP-1 through AAP-4 are summarized. The EMC programs of the Manned Spacecraft Center (MSC) and the Marshall Space Flight Center (MSFC) for AAP, including EMI control specifications imposed and EMC testing philosophy adopted, are the same as their respective programs for the Apollo Program. MSFC will perform EMC tests on the various space vehicle modules under their control to demonstrate a minimum margin of 6dB between the desired signal and interference noise present at the most critical point of the various subsystems of these modules. MSC will demonstrate the EMC of the various space vehicle modules under their control through functional testing without demonstration of any safety margin.

Both the Electrical Panel and the Instrumentation and Communications (I/C) Panel have responsibilities in the area of EMC for AAP. The Electrical Panel has the responsibility for control of EMI in the interface wiring between the various space vehicle modules and between the space vehicle modules and the launch facilities. The I/C Panel assumes all other responsibilities in achieving EMC of the interfaces of the integrated AAP space vehicle. Specific test plans to demonstrate EMC of the integrated AAP space vehicle cannot be developed by the I/C Panel until the master test flow plan for AAP has been formulated by the Test Definition and Planning Group and approved by the program managers of the various Centers.

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MEMORANDUM FOR FILE

1.0 Introduction

The current electromagnetic interference (EMI) control and electromagnetic compatibility (EMC) validation efforts in the Apollo Applications Program (AAP) for missions AAP-1 through AAP-4 are summarized in this memorandum. The Marshall Space Flight Center (MSFC) and the Manned Spacecraft Center (MSC) have the responsibility to provide free of detrimental EMI effects the various space vehicle modules and associated ground support equipment (GSE) under their respective control for subsequent integration with other modules not under their respective control. MSFC has this responsibility for the Saturn IB Launch Vehicle, the Orbital Workshop (OWS), the Multiple Docking Adapter (MDA), and the Apollo Telescope Mount (ATM), while MSC has this responsibility for the Airlock Module (AM), the Command Module and Service Module (CM-SM), and the Lunar Module (LM). Various intercenter panels have the responsibility to insure electromagnetically compatible space vehicle module interfaces and overall EMC of the integrated space vehicle and/or cluster.

The efforts of the NASA Centers and their contractors toward achieving EMC of the various individual AAP space vehicle modules and of the intercenter panels toward achieving EMC of the integrated AAP space vehicle are discussed in the following paragraphs.

2.0 Marshall Space Flight Center

With the exception of the Saturn IB Launch Vehicle used in mission AAP-2 whose S-IVB stage will be modified to form the OWS, the Saturn IB Launch Vehicles used in AAP will be the same as those used in the Apollo Program. Consequently, no AAP peculiar EMI control or EMC validation activities are planned by MSFC on any of the S-IB and S-IVB stages and Instrument Unit (IU) of the various Saturn IB Launch Vehicles used in AAP except for the S-IVB/IU of the launch vehicle used for mission AAP-2.

Electromagnetic compatibility control plans have been written by MSFC covering the OWS[1], the MDA[2], and the ATM[3]. These plans include: (a) specific requirements for the design and test of all electrical and electronic equipment and subsystems of the particular space vehicle module, as well as the integrated module, including specifications imposed any any amendments to their requirements, (b) design guidelines on grounding, wiring, shielding, filtering, etc., (c) MSFC organizational responsibilities, and (d) contractor requirements. In addition to the format, the specific contents of these three control plans are also largely identical.

As is the case for all electrical and electronic equipments of the Saturn Launch Vehicles in the Apollo Program, the design and test of the electrical and electronic equipments of the OWS, MDA, and ATM are required to comply with the requirements of specification MIL-I-6181D (Military Specification, Interference Control Requirements, Aircraft Equipment). Electrical bonding of all metallic elements of the structure and equipment enclosures of the OWS, MDA, or ATM will be in accordance with MIL-B-5087B (Military Specification, Bonding; Electrical - for Aircraft) in order to achieve a unipotential structure. The requirements of specification MIL-E-6051C (Military Specification, Electrical-Electronic System Compatibility and Interference Control Requirements for Aeronautical Weapon Systems, Associated Subsystems and Aircraft) apply to the completely integrated OWS, MDA, or ATM. As is specified in MIL-E-6051C, tests will be performed to demonstrate a minimum of 6 dB of margin between the desired signal and the interference noise at the most critical point of the various subsystems of these space vehicle modules. During this EMC test on the integrated OWS, MDA or ATM, the hardwire interfaces with other space vehicle modules will be simulated by appropriate cable lengths and loads such as relays.

3.0 Manned Spacecraft Center

In the current EMC program of MSC for Apollo, the prime contractors for the CM-SM (North American Rockwell-NR) and the LM (Grumman Aircraft Engineering Company - GAEC) are contractually required to design and test all electrical or electronic equipments of the CM-SM or LM per the requirements and limits of specification MIL-I-26600 (Military Specification, Interference Control Requirements, Aeronautical Equipment) as amended by MSC addendum MSC-EMI-10A (Addendum to MIL-I-26600, dated October 17, 1963, National Aeronautics and Space Administration), or the equivalent. In addition, NR and GAEC are

contractually required to design the respective integrated spacecraft (CM-SM or LM) using the military electromagnetic compatibility specification MIL-E-6051C as a guide and attempting to maintain at least 6 dB safety margin against possible EMI caused malfunctions or perforamnce degradations. However, tests to demonstrate this 6dB safety margin are not contractually required and will not in general be performed by either NR or GAEC except on pyrotechnic circuits. It is the MSC philosophy that any electromagnetic incompatibilities in the integrated spacecraft would be uncovered during system buildup tests which include individual subsystems functional tests, integrated systems functional tests, and finally simulated mission tests. It should be noted that EMI control plans for the CM-SM and LM in the Apollo Program were prepared by NR and GAEC, respectively, outlining their individual EMC programs and philosophies.

The EMC programs and philosophies of NR and GAEC in the Apollo Program will not be changed for the Apollo Applications Program. All new or modified electrical and electronic equipments to be added to the CM-SM or LM of the Apollo Program for AAP will be designed and tested to the requirements of specification MIL-I-26600 as amended by MSC addendum MSC-EMI-10A, or the equivalent. Equipment and systems qualified in the Apollo Program will not be redesigned or retested. Electromagnetic compatibility of the integrated CM-SM or LM for AAP will be demonstrated through the systems buildup functional tests. During these functional tests, the hardwire interface between the CM-SM or LM and other space vehicle modules will be simulated by appropriate loads and cable lengths.

The McDonnell Douglas Corporation (MDC), prime contractor for the AM, has prepared an electromagnetic interference control plan for the AM(4). This plan contains the design guidelines, design requirements, and test requirements established to control EMI generation by and EMI susceptibility of AM electrical and electronic equipment and to assure self-EMC of the AM. All new or modified electrical and electronic equipments for the AM will be designed and tested to the requirements of specification MIL-I-26600 as amended by MSC addendum MSC-EMI-10A. However, all electrical and electronic equipment qualified in the Gemini Program to be used in the AM will not be retested or modified to meet the design and test requirements specified in AM EMI control plan. Any problem areas in achieving EMC of the AM by following this policy will be resolved by making compensations in the design of the integrated AM. No specific EMC tests are planned for the integrated AM to ascertain the existence of a safety margin between the interference present and the susceptibility of critical subsystems. Normal

subsystem buildup and interface functional tests will be used to demonstrate the self-EMC of the AM. The hardwire interface with other modules will be simulated by appropriate loads and cable lengths.

4.0 Intercenter Panels

The Electrical Panel and the Instrumentation and Communications (I/C) Panel are the intercenter panels active in the area of electromagnetic compatibility in the Apollo Applications Program. By definition, these intercenter panels are only concerned with the interfaces between the various space vehicle modules under the control of different Centers. Each Center retains the authority to approve or disapprove requests submitted by their respective contractors for waivers to EMI requirements contained in the appropriate EMI control plan or contract.

The Electrical Panel has the responsibility for control of EMI in the interface wiring between two space vehicle modules or between a space vehicle module and GSE and/or launch facilities when each is under the control of a different Center. This EMI control will be accomplished through the specification and implementation of bundling, routing, twisting, shielding, and grounding requirements for wiring and cabling across the interface. To date, none of the interface control documents defining these electrical wiring interfaces have been issued by the Electrical Panel.

The responsibilities of the I/C Panel in the area of electromagnetic compatibility as outlined in its charter include definition and resolution of interface problems associated with radio frequency interference and assurance of electromagnetic compatibility of the interface (conducted and radiated) between the various space vehicle modules, between the integrated space vehicle and launch facilities and GSE, and between the space vehicle and the stations of the Manned Space Flight Network (MSFN). The I/C Panel has assigned to the Electromagnetic Compatibility (EMC) Subpanel of the I/C Panel the following specific tasks:

(a) Recommendation of frequency allocations to transmitters and receivers used in AAP based on the results of a radio frequency interference analysis.

(b) Recommendation of proper bonding and grounding procedures and practices to minimize EMI and

to provide protection against lightning and static charge accumulation effects.

(c) Definition of a test program to demonstrate compatibility of the overall AAP cluster.

(d) Insure mutual exchange of pertinent EMC information betweeen Centers.

The International Business Machines (IBM) Huntsville Engineering Operation developed a number of computer programs of varying sophistication to perform beat frequency analyses for use in the Apollo Program. One of these computer programs calculates the spurious frequencies that could be generated which fall within the 3dB passband of the on-board receivers through mixing of the fundamental frequencies (up to the fourth harmonic) of the on-board transmitters taken two, three and four at a time. A second computer program can be used to predict the amplitude level of those spurious frequencies falling within the 3dB passband of the on-board receivers. A beat frequency analysis will be performed for AAP using the two computer programs described above after the agreement between NASA and the Department of Defense (DOD) on continued, but restricted, NASA use of standard telemetry channels in the 225-260 MHz frequency band through January 1, 1975, has been finalized.

The I/C Panel generates interface control documents (ICD's) which define the instrumentation and communication interfaces between the various space vehicle modules of the AAP cluster under the control of different Centers and which serve as the formal specification for establishing the interface requirements. These ICD's contain a section devoted to electromagnetic compatibility which includes requirements on bonding, grounding, shielding, and conducted and radiated electromagnetic interference generation and susceptibility at the interface. It should be noted that these ICD's do not cover the physical wiring requirements of the interface. Preliminary drafts of these ICD's covering the CM/MDA, MDA/AM, AM/OWS, ATM/LM, and LM/MDA interfaces are available.

Although a preliminary EMC test plan for AAP has been written by the EMC Subpanel, no further action can be taken in this area until the master test flow plan for AAP has been developed by the Test Definition and Planning Group

(TD&PG) and been approved by the program managers of the various Centers. Until this master test flow plan is developed, the degree of sophistication of the simulators used during the integrated testing of the various individual space vehicle modules of AAP cannot be defined. As indicated earlier, the simulators currently planned for use by the Centers consist of simulated loads and cable lengths.

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REFERENCES

1. MSFC Document 50M13087, Orbital Workshop System Electromagnetic Compatibility Control Plan, May 1, 1968.

2. MSFC Document 50M12968, Multiple Docking Adapter Electromagnetic Compatibility Control Plan, November 1, 1967.

3. MSFC Document 50M12725, Apollo Telescope Mount Electromagnetic Compatibility Control Plan, February 15, 1967.

4. MDC Report E853, Airlock Electromagnetic Interference Control Plan, April 17, 1967.

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